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Abstract

DEVELOPMENTS IN SOLID MODERATOR MATERIALS

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Work conducted in the past several years at a number of laboratories in the United States has greatly extended the knowledge on solid moderator materials. Most effort has been devoted to three classes of materials: carbons and graphites, beryllium oxide, and metal hydrides. Some work has been reported on beryllium, although this material has not found extensive use as a moderator. In this review of solid moderators emphasis is placed on recent developments, potential problems, and especially on the radiation effects in these materials.

Graphite is used to greatest advantage in large power reactors or in applications in which the moderator is subjected to very high temperatures. Emphasis has, therefore, been placed on long-term irradiation studies in which the neutron dose approaches that expected during the lifetime of an advanced power reactor, on radiation effects at high temperatures, and on gas - graphite compatibility studies. Irradiation studies have now been extended to doses of 1.6×10^{22} nvt (E 0.18 MeV) at 800C. The most important effects observed relate to dimensional stability. Much more limited data have been obtained for irradiation temperatures up to 1200C.

Factors that affect the radiation-induced dimensional changes in graphite have been identified. For example, it has been determined that non-crystalline carbons contract at a much higher rate than the more crystalline graphites. These and other studies have led to a theory for radiation-induced dimensional changes that occur at high temperature. Based on this theory, new materials, which should have improved properties, were fabricated; irradiation tests are in progress.

The creep and mechanical properties of graphite have been studied under a variety of conditions, both in and out of reactor. It has been determined that an external stress significantly modifies the radiation-induced dimensional changes at high temperature.

Graphite is finding increasing use as a fuel matrix, fuel can, and coolant tube for high-temperature gas-cooled reactors, and potential problems in these applications are being explored. Compatibility of the graphite with trace amounts of oxidizing gases in helium-cooled reactors is a problem that will require careful purification of the gas.

Beryllium oxide has good strength at elevated temperatures, high thermal conductivity, and other favorable physical properties, and also is a good moderator with a relatively low absorption cross section. The major question in the use of beryllium oxide is its stability after extensive irradiation. A considerable amount of information has been obtained recently on this question. The range of conditions tested include neutron doses up to 2.8×10^{21} nvt (E 1 Mev.) and irradiation temperatures from 100 to 1200C. Earlier reports of powdering at low temperatures and high exposures have been confirmed; however, at high temperatures the dimensional stability is greatly improved. Radiation-induced expansion is attributed to three factors: crystallographic lattice expansion, grain-boundary separation, and helium bubble formation. It appears that reactor operating conditions may be chosen to control expansion from the first two effects, but a better understanding of the contribution to damage of helium formation is needed. Factors such as sample size, grain size, preferred orientation and purity have also been examined and were found to influence the irradiation behavior.

Zirconium and yttrium hydrides offer definite weight and volume advantages, and, therefore, find use in special moderator applications. However, the loss of hydrogen by thermal decomposition limits their use to relatively low temperatures, although the useful temperature range can be extended with cladding. The thermal stability of yttrium hydride is considerably better than zirconium hydride, and recent physical-property determinations have greatly enhanced its usefulness in engineering applications. However, more information on the radiation effects in both yttrium and zirconium hydrides is needed.